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16. Abstract

The present report constitutes an attempt at an explanation of habituation and recruitment as it applies to the vestibular apparatus. Multiple rotatory, thermal, galvanic and pendular stimuli do not result in habituation. The peripheral vestibular receptor always reacts in the same manner following repeated stimuli. Habituation is a central process, with which occurs in nervous and central lesions; under certain conditions which will be discussed later on, the concept of "positive habituation" is recommended.

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POSITIVE HABITUATION AND VESTIBULAR RECRUITMENT

M. Emami-Nouri[1]

Disturbances in the cupular endolymph system usually manifest themselves as a result of repeated stimulation in the form of an increase in vestibular excitability which is termed vestibular recruitment. /183*

Numerous studies with contradictory results appear at first glance not to explain the generally known physiological phenomenon of habituation, particularly habituation of the vestibular apparatus.

Bárány (1967) found no habituation in various vestibular stimulatory techniques; thus, for example, he subjected a patient to 5-10 rotations daily for 14 days and was unable to detect any habituation. He found it difficult to accept, however, that a neurophysiological characteristic, which is otherwise generally observed, could not be observed in the vestibular system. He speaks of habituation without having objectivized the latter. Similarly, Jung and Toennies (1948), clearly referring to a sensation of dizziness, observed no significant decreases in the reaction following multiple rotations.

Likewise, Greiner et al. (1969), following numerous oscillations in a time interval of 2 minutes, were unable to detect the phenomenon of habituation in normal subjects. Cawthorne (1956), in studies on human subjects, was able to detect significant habituation only in the case of cupulometry. Osterhammel et al. (1968), even in the case of repeated, very strong stimuli, observed no habituation. In repeated tests with stimuli near the threshold, Fluur et al. (1967) observed an increase in the latent period, but not in the case of superthreshold stimuli. Jongkees (1960), in contrast to Maspetiol et al. (1965), observed no decrease in the maximum angular velocity of the slow phase and the nystagmic frequency. Mittermaier (1952), with repeated caloric stimuli, observed a decrease in the reaction only in the case of individual nystagmic

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*Numbers in the margin indicate pagination in the foreign text.

parameters. In contrast to these experimental results, Hazeyama (1963), Henriksson et al. (1961), Brown (1965) and Von Arxt (1964) found a decrease in the reaction in the sense of habituation in animals and man.

Hallpike and Hood (1953) termed vestibular reaction decreases as a result of adaptation or habituation as a "response decline". Almost all authors, in contrast to the nystagmic reaction, observed a clear habituation in cupulometry. Aschan (1954), Cawthorne (1956) and Kornhuber (1966).

TABLE 1. POSITIVE HABITUATION /184

Individual Methods of Stimulation	Caloric Stimuli	Rotatory Stimuli	Oscillatory Stimuli
Oscillatory stimuli	2	1	0
Rotatory stimuli	12	2	0
Caloric stimuli	14	12	2

The frequency of positive habituation of individual methods of stimulation in 21 patients with acoustic neurinoma. (Only a few of the patients were subjected to the oscillation test.)

Collins (1963, 1964, 1967), Collins and Guedry (1962) and Collins et al. (1962) studied the interference effects of various vestibular stimuli and other factors such as alertness, light intensity and the like. Thus, for example, he introduced a series of rotatory stimuli between 2 monaural thermal stimuli, and observed a decrease in nystagmic frequency.

These contradictory findings are partially based upon the evaluation of only 1 or a few nystagmic parameters, and also on the fact that in the above tests no strict separation was made between central and peripheral processes and their evaluation.

We distinguished 3 mechanisms in which a decrease in reaction can occur.

Fatigue, Adaptation and Habituation

These 3 processes have a common effect, a decrease in reaction, but different causative mechanisms.

Fatigue is a functional weakening "*sui generis*"; adaptation corresponds to a decrease in reaction as a result of a single stimulus lasting a long period of time; the efferent fibers acquires an important role, which we shall not discuss in further detail here. Adaptation is a protective mechanism, which affects the entire vestibular organ in a reflex manner and is hardly affected by unspecific stimuli. Habituation is expressed in a decrease of the reaction following multiple repeated stimuli. It is a purely central process and depends upon a number of factors, such as the state of consciousness, medications, alcoholic abuse, the patient's will power and many other sensory physiological stimuli. The decrease in the nystagmic resection following repeated adequate stimuli without participation of the above-mentioned factors is termed *positive habituation*, with the nystagmic reaction in the sense of vestibular intensity must be taken into account, since it is the only one which takes all of the nystagmic parameters into account. It corresponds to the sum of the right and left nystagmuses, evoked experimentally with equal stimulatory intensity, in a labyrinth according to the formula GA/T (Emami-Nouri, 1972).

Successive stimuli with hot or cold water, rotation with various degrees of acceleration and deceleration, as well as oscillation in the Barany chair in 120 normal subjects, resulted in no decrease in vestibular level. In contrast to this, all cases diagnosed as acoustic neurinoma (21 patients) showed at least an attempt at stimulation in contrast to positive habituation. In 13 patients, the diagnosis was confirmed by operation; 2 cases which we evaluated as negative but were subsequently operated upon proved negative following the operation. Table 1 shows the frequency of *positive habituation* following various kinds of stimuli in 21 patients with clinically or operatively detected acoustic neurinoma. Stimuli of a caloric and rotatory nature were employed as well as oscillation. The results were calculated in the sense of vestibular level (Pv).

The following is our attempt at explaining why, in the case of nerve lesions, as well as in acoustic neurinomas, there is a significant habituation /186 and a rather prolonged dishabituation (our own observations): the impulses which are caused by partial damage to the nerve elements and the resultant displacement of the resting potential has such a stressful effect upon the habituation centers that a further stress can only be answered by a true decrease in the reaction. Likewise, prolonged dishabituation is caused by central dysharmonis. Following numerous studies, Collins has shown that the decrease in the nystagmic reaction is specific for repeated stimulations; i.e., a calorically habituated vestibular apparatus can display normal per- and postrotatory values. The findings of Collins correspond to those of Klijn and Ek (1957) as well as those of Philipszoon (1959).

A certain spectrum of stimuli causes habituation; the central nervous system constructs a copy which is retained for a long period of time and is highly specific. The cupular endolymph system has only a transfer role and is not itself involved in habituation.

The central processes in habituation appear to be the same as compensation. Vestibulary stimuli carried out at intervals of hours and days with patients with unilateral problems evoke hyperreflexia and directional predominance toward the healthy side. Further studies in the course of days or months reveal a decrease in the directional preference with a slight lessening of hyperreflexia. Patients with an absence of subjective complaints with unilateral vestibular problems display uniform right and left nystagmus and an equilateral *compensation triangle*. Figures 1 and 2 show the course of the compensation process in which these *compensation curves* and *triangles* determine the prognosis. We found these results both in patients with operative lesions and in cases with neuronitis of the vestibular nerve. (This phenomenon can also be employed therapeutically.)

Very frequently, patients with disturbed cupular endolymph systems, such as Ménière's Disease, displayed the phenomenon of *vestibular recruitment*. It shows up in reduced vestibular power as an increase in stimulibility; the latter occurs with an increase in reaction with repeated successive stimuli. In the graphic representation of the vestibulogram, it can be recognized as a discontinuity in the curve in the stimulibility-standard area. The reason for this can be found in a lability of the vestibular apparatus. Von Békésy (1939) and /187
later Greiner et al. (1969) were able to observe, in the case of stimulation near the threshold with the Barany chair, toward one side but not toward the other. Greiner states that this is vestibular recruitment. We are of the view, however, that there must be primarily a reduced stimulatibility, because only in that case would it make sense to have recruitment in the sense of a balancing of the vestibular excitability in the direction of the normal area.

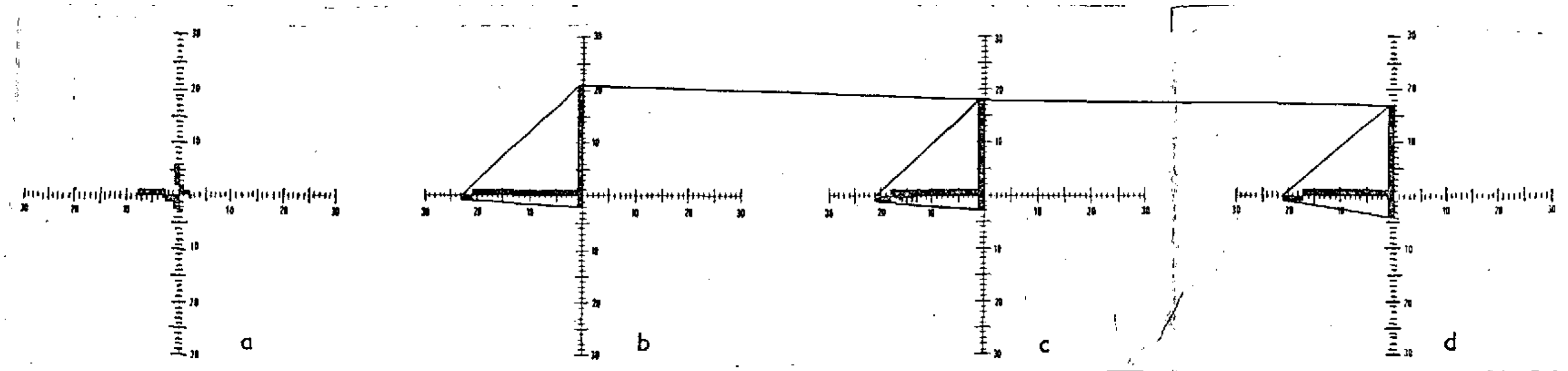

Figure 1. Gertrude K 46 a. Acoustic neurinoma. a, 14 September 1971: before the operation: spontaneous nystagmus: 0. Unterberger and chalk-line test: rotation to the left. Pv-vestibulogram: reduced excitability on the left side, ipsilateral directional preference. b, 1 October 1971: 4 days after the operation: complete vestibular failure on the left, transitory spontaneous nystagmus as well as hyperreflexia on the right. c, 29 February 1972; d, 3 July 1972. Spontaneous nystagmus: 0. The compensation curve is flat (prognostically unsatisfactory). Non-equilateral compensation triangles. Complete compensation not anticipated for a long period of time.

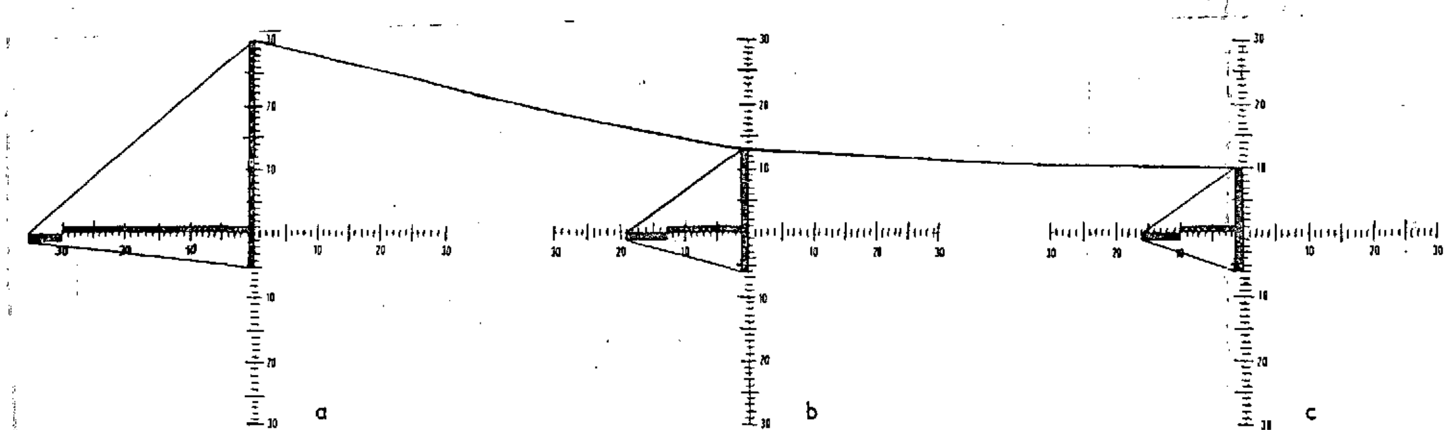

Figure 2. Joseph W 58 a. Neuronitis, N. Vest. Sinist. a, 12 May 1972: complete vestibular failure on the left, right-hand spontaneous nystagmus, hyperreflexia on the right. b, 26 May 1972: the patient is subjectively free of complaints. Unterberger as well as chalk-line test show no significant pathological rotation or deviation. No spontaneous nystagmus. Hyperreflexia on the right is reduced up to 30 with respect to the initial value. The compensation curve shows a steep course. The compensation triangle is approximately equilateral (prognostically favorable). c, 17 August 1972: compensation has not advanced significantly since the last test. Curve shows the tendency to be flat. A long time still remains until complete compensation.

TABLE 2. VESTIBULAR RECRUITMENT

Individual Methods of Stimulation	Caloric Stimuli	Rotatory Stimuli	Oscillatory Stimuli
Oscillatory stimuli	2	1	0
Rotatory stimuli	22	4	1
Caloric stimuli	2	22	2

Frequency of vestibular recruitment of individual stimulation methods in 31 patients with Ménière's Disease. (Only part of the patients were subjected to the oscillation test.)

In 35 patients with Ménière's Disease, 31 were found to show vestibular recruitment, but this could not be found in all types of stimulation. Table 2 shows its frequency in 31 patients with Ménière's Disease, following different kinds of stimulation. Greiner was able to find this phenomenon in 5% of his cases, but in our case this number is much higher. This discrepancy seems to find its origin in the fact that for determining the vestibular recruitment we use not only the oscillation test but also other methods of stimulation such as rotation and calorization. As we can see from Table 2, recruitment does not occur after all types of stimulation and is relatively rare even after oscillatory stimulation.

To determine the vestibular habituation as well as vestibular recruitment, we used monaural calorization with constant temperature. This meant that one labyrinth was frequently stimulated at time intervals of 3 minutes. The results were calculated in the form of vestibular potency and plotted on a cross diagram. If multiple caloric stimulations with existing subexcitability failed to produce any habituation or vestibular recruitment, another test was required with rotatory or oscillating chairs. The rotation test was carried out by us in such a way that younger patients were accelerated at $0.5°/sec^2$ and older to old patients with $0.9°/sec^2$ up to a final velocity of $100°/sec^2$, and braked after 10 sec. The per- and postrotatory values were also calculated using the formula GA/T and plotted on the cross diagram. The results of the caloric stimulations on the left side, as well as the per- and postrotatory values following rotation to the left, were plotted on the cross diagram on the right and the results of the stimulations of the right side on the left. The right or left nystagmus was plotted on the ordinate above or below the abscissa.

Figures 3 and 4 show a positive habituation as well as a vestibular recruitment following multiple thermal and rotatory stimuli. /188

Determination of changes in the reaction following oscillation is also highly arbitrary. A second oscillatory test and evaluation of the vestibulogram on the basis of frequency (Greiner et al., 1969) or according to vestibular power (Emami-Nouri, 1972) generally allows a very good evaluation of the change in reaction. Figures 5 and 6 show the frequency vestibulogram for habituation and recruitment.

Multiple galvanic stimuli generally produce the same reaction; for this reason this method does not seem to us to be suitable for determination of positive habituation or vestibular recruitment.

Various interpretations have been given to the concept of habituation used in the literature. Thus, Jongkees understands it to be a decrease in nystagmic frequency, Greiner, Collard and Conraux see it as an increase in the latter and Mittermaier sees it as a decrease of the nystagmus time and amplitude. The literature contains a certain discrepancy concerning the concept of vestibular habituation, which we would like to define under the concept "*positive habituation*". We understand it to mean: "Reduction of vestibular potency following multiple adequate stimulation without involvement of interference factors."

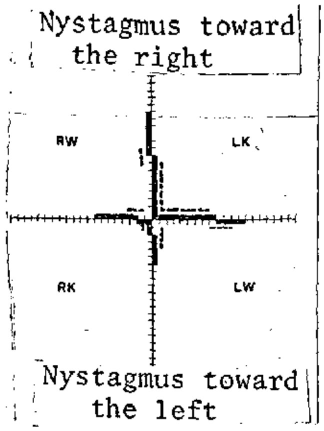

Figure 3. Maria C. 44 a. Acoustic neurinoma on the right. Caloric values. Pv vestibulogram. Positive habituation. Decrease in reaction predominantly on the right. —: First test. ---: Second test.

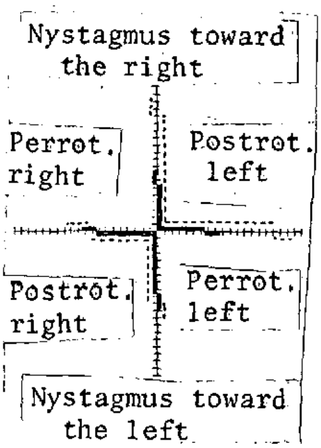

Figure 4. Aurelia N. 61 a. Ménière's Disease on the left. Rotatory stimulation. Pv vestibulogram. Vestibular recruitment on both sides, predominantly on the left, manifested after the second stimulation. —: First test, ---: Second test.

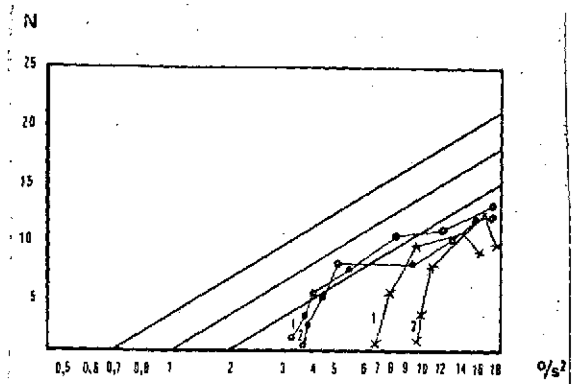

Figure 5. Gertrude K. 46 a. Acoustic neurinoma on the left. Oscillatory stimulation. Frequency vestibulogram. Positive habituation. Double oscillation. In 2 tests, there was increased stimulation threshold (left [×] stronger than right [•]). Positive habituation results from an increase in the stimulation threshold after the second oscillation. Commas indicate decimals.

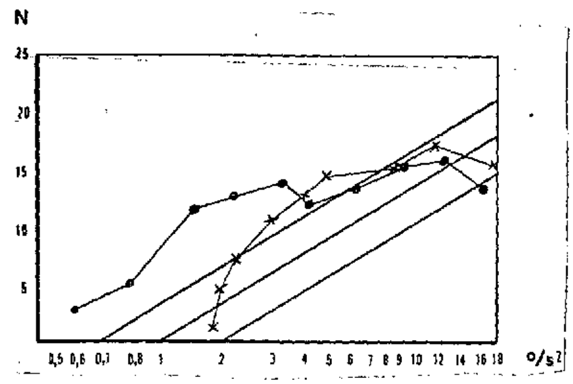

Figure 6. Heinrich G. 40 a. Ménière's Disease on the right. Oscillatory stimulation. Frequency vestibulogram. Vestibular recruitment. With strong and moderate stimulation intensity the right nystagmus curve is in the normal region (•). With the lower stimulation intensity, there is a clearly reduced stimulation threshold. Commas indicate decimals.

Vestibular recruitment can be viewed as a manifestation of a labyrinthine-vestibular disturbance. Hence, clinical consequences for differentiation of central-nervous and labyrinthine-vestibular disturbances results.

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